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Modeling and Characterization of Cavity Backed Circular Aperture Antenna With Suspended Stripline Probe Feed

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MODELING AND CHARACTERIZATION OF CAVITY BACKED CIRCULAR APERTURE ANTENNA WITH SUSPENDED STRIPLINE PROBE FEED

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Abstract: The paper presents the numerically simulated input impedance of a cavity backed circular aperture antenna with suspended substrate stripline probe feed. The simulation is based on the finite element method. The results show the input impedance or the return loss as a function of the frequency with the probe dimensions as parameters. The simulated results are validated by measurements at millimeter-wave frequencies.

I. INTRODUCTION

Future space borne microwave/millimeter-wave systems in near-Earth orbits for communications, inter-satellite links and high-resolution mapping will require antennas which have high gain, high efficiency, low profile, light weight, excellent temperature stability and low cost. As the frequency of operation increases from the microwave to the millimeter-wave band, the attenuation of planar transmission lines increases due to conductor loss [1]. Consequently in planar array antennas, the feed network loss increases with frequency. Besides conductor loss, the loss of power due to surface waves is also a concern in planar arrays. The net effect of these losses is the reduction in the array gain and efficiency. An effective method to lower these losses and enhance the efficiency and gain is to construct the feed network using low loss transmission lines such as, rectangular waveguides [2], parallel plate waveguides [3], radial lines [4] or suspended substrate lines [5]. The suspended substrate line is particularly attractive because it makes use of a very thin dielectric sheet which has low loss tangent and excellent temperature stability such as, RT/duroid® 5880 [6]. In addition since the substrate is suspended between ground planes, the effective dielectric constant is close to that of free space and hence surface wave losses are negligibly small. Recently a cavity backed circular aperture antenna with a suspended substrate stripline feed has been demonstrated [7]. In the past this type of radiator has been analyzed using Green's function method and an expression for the input impedance has been presented [8].

The analysis presented in this paper is based on the finite element method (FEM). The analysis takes into account the effect of the rectangular opening through which the suspended stripline enters the cavity. In addition, the analysis takes into account the exact geometry of the probe in the cavity. The numerical results include the input impedance of the cavity backed circular aperture antenna with suspended stripline probe feed. The results show the variation in the input impedance or the return loss as a function of the frequency with the probe dimensions as parameters.

II. ANTENNA ELEMENT CONSTRUCTION

A cavity backed circular aperture antenna with suspended stripline feed is shown in Figure 1. The antenna element [7] consists of a thin dielectric substrate of thickness d supported between two cylindrical waveguides of axial height h_1 and h_2. The lower waveguide is terminated in a short circuit so as to form a cavity. The radius r of the waveguide is chosen such that the dominant TE_{11} mode propagate but the next higher order TM_{01} mode is cut off. The TE_{11} mode is excited by extending the strip conductor of the suspended stripline through an opening (a x b) in the wall thus forming a probe of width W_1 and length L_1. The probe impedance is matched to the suspended stripline impedance by proper choice of W_1, L_1, taper length L_t and the cavity height h_2. The antenna radiates with a linear polarization along the y-direction.

III. NUMERICAL MODEL

A schematic view of the numerical model for the cavity backed circular aperture antenna is shown in Figure 2. The cavity is excited by a narrow probe realized by extending the strip conductor of the suspended stripline through an opening in the cylindrical wall. Further to minimize the effect of step discontinuity reactance due to the difference in the width of the probe and the strip conductor on the input impedance a linear taper is used in between. The circular aperture is terminated in an isotropic absorber to simulate free space environment. The model uses tetrahedral element and edge-based basis function. Perfect electric conductors are assumed throughout the model and hence conductor losses are zero. The problem generates about 150,000 unknowns and is solved on a computer with a clock speed and memory of 400 MHz and 400 Mbytes respectively. Hence, the computation of input impedance at any frequency takes about an hour.

IV. NUMERICAL AND EXPERIMENTAL RESULTS

The computed return loss as a function of the frequency for a given set of probe dimensions is shown in Figure 3. The preliminary results show that the return loss is better than −10.0 dB (VSWR <2.0) over 2 percent bandwidth centered at about 56.0 GHz. The experimental investigation of this circuit and efforts to improve the bandwidth are in progress.

V. CONCLUSIONS

The paper presents a finite element model for the input impedance of a cavity backed circular aperture antenna excited by a suspended stripline probe feed. The computed results show the return loss as a function of the frequency for a particular probe dimensions. Initial results show that the return loss is better than −10.0 dB over 2 percent bandwidth centered at about 56.0 GHz.

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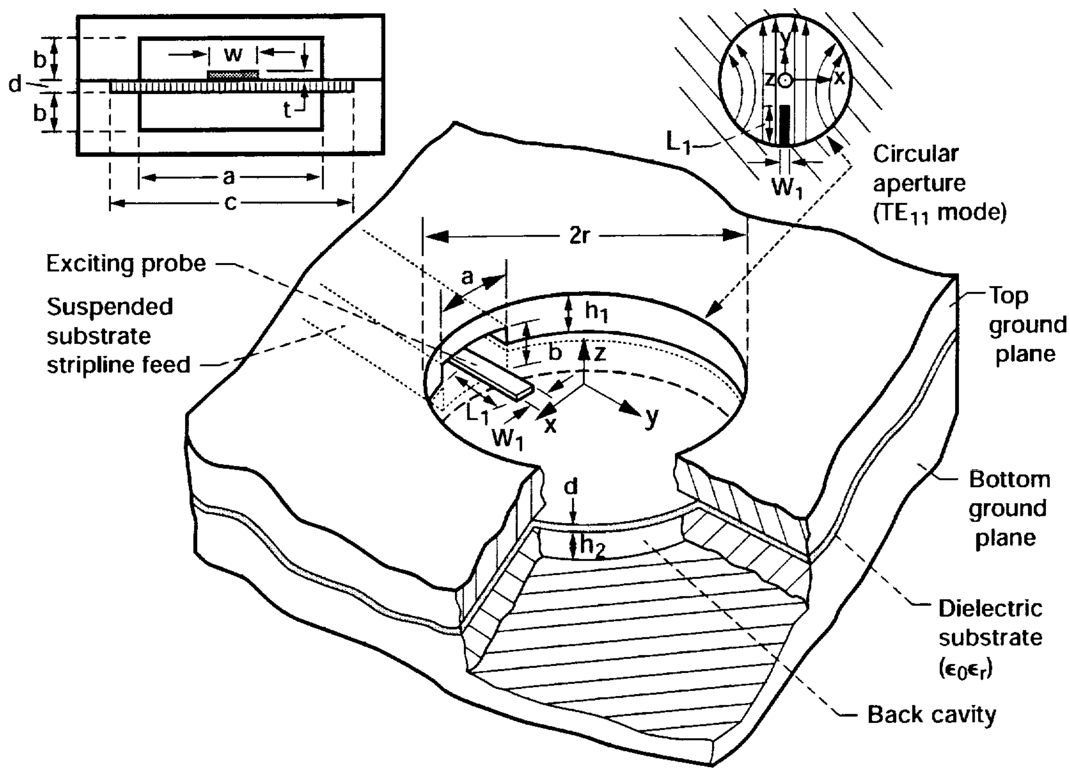

Figure 1.-Cavity backed circular aperture antenna with suspended substrate stripline (SSS) feed. The inset on the top left and right show the cross-section of the SSS and the electric field distribution for the TE_{11} mode respectively. The parameters (in inches) are d = 0.005, ϵ_r = 2.22, h_1 = 0.25, h_2 = 0.10, r = 0.075, a = 0.074, c = 0.09, b = 0.016, W = 0.04, W_1 = 0.0175, L = 0.06, L_t = 0.066.

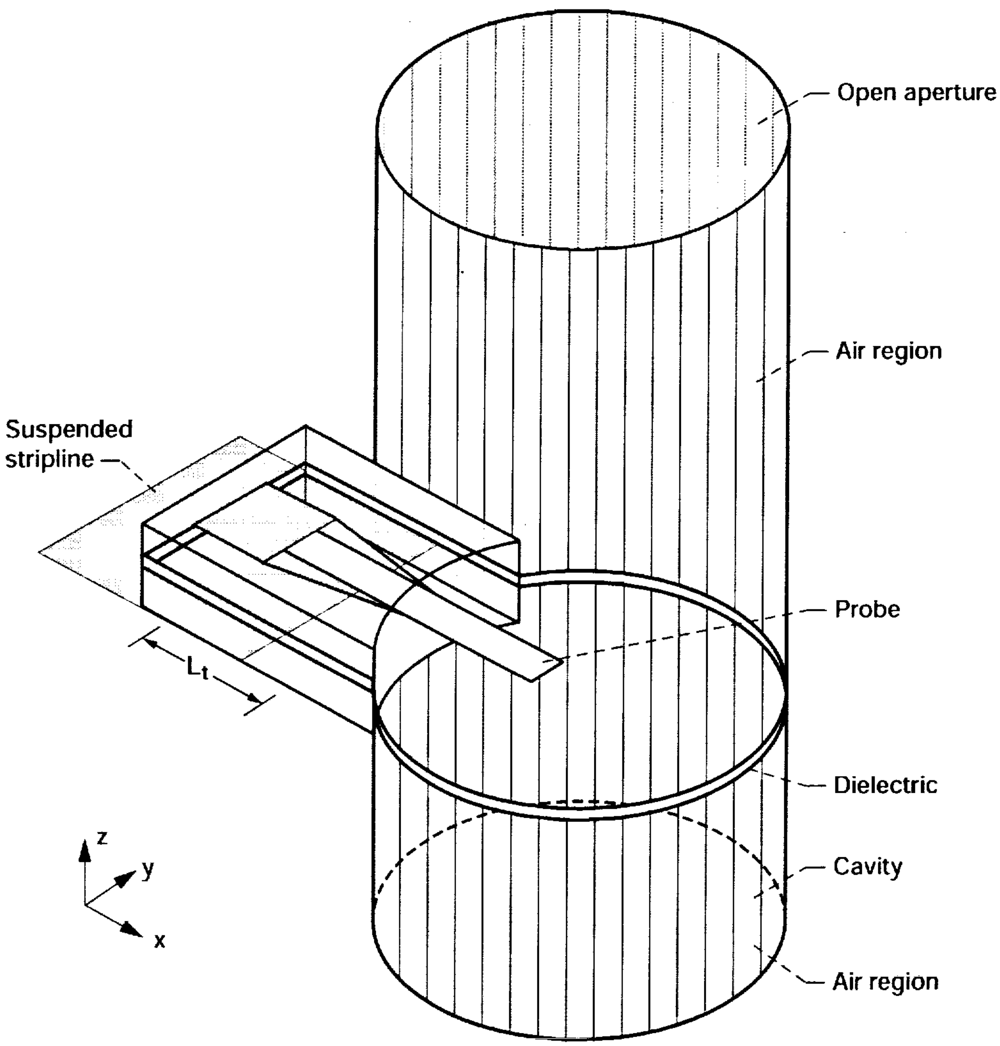

Figure 2.- Numerical model for the antenna.

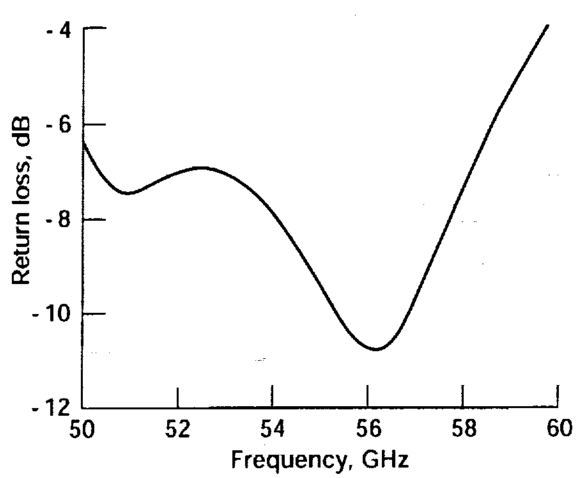

Figure 3.- Computed return loss as a function of the frequency.

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13. ABSTRACT ***(Maximum 200 words)***

The paper presents the numerically simulated input impedance of a cavity backed circular aperture antenna with suspended substrate stripline probe feed. The simulation is based on the finite element method. The results show the input impedance or the return loss as a function of the frequency with the probe dimensions as parameters. The simulated results are validated by measurements at millimeter-wave frequencies.

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